Quantifying The Advantages of Better Detector Resolution

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It is a truism that all else being equal, higher resolution is always better. In optical wavebands, where large collecting areas are relatively easy to obtain, resolutions of 100,000 or higher are regularly used. In the X-rays, such high resolutions are less useful, since the resolution set by thermal broadening is $R \approx 410\sqrt{M/T}$ for an ion of mass M in atomic mass units and temperature T in keV. This limits the "interesting" range of resolutions to a maximum of ~ 10,000; beyond this, the line profiles from X-ray emitting plasmas would be dominated by simple thermal broadening. Of course, absorption spectra of cool plasmas would benefit from higher resolutions, so ~ 10,000 is not a hard upper limit. Given the complexity of X-ray spectra, there is no a *priori* reason why any particular **lower** resolution would be ideal for all tasks.

Ideally, a minimum resolution (probably as a function of wavelength/energy) could be determined by careful scrutiny of a range of existing spectroscopic studies, and seeing in practice what resolution was needed. This could be complemented by asking the authors of those papers what could have been achieved with higher resolution. However, X-ray spectroscopists have only recently had access to a substantial amount of high resolution (R ~ 1000) data, and so as a field there is relatively little accumulated wisdom about where higher resolution and/or narrow line shape is most important.

We can attempt to quantify the advantages of improved resolution by examining how improved resolution increases our ability to distinguish emission lines. The first question is: which emission lines need to be resolved? Clearly, not all emission lines are created equal. Resolving the Lyα doublet, which is nearly always in a 2:1 ratio, is of limited value except when trying to measure optical depths in individual ions, and even then there are easier methods. However, density-dependent lines are often interesting, since their density-sensitivity is usually caused by a metastable level which can be collisionally (de)excited. As a result, the line may also be sensitive to radiative (de)excitation or other non-equilibrium effects. Resolving these lines, then, is a reasonable metric. However, it can be biased if a single ion has many such lines compared to other ions. Using the Astrophysical Plasma Emission Code and Database (APEC/APED; Smith et al. 2001) we generated spectral models for a range of temperatures and densities, and then searched the results to find up to five bright lines (between 1-30°A) from each ion that show at least 10% variation with density at particular temperatures. At 10^7 K, there are ~ 100 such lines; at $10^{6.5}$ K, ~ 50.

We then compared this list to all the lines emitted from a 10^7 K plasma, and found out how many would be "unblended." We assumed here that "unblended" means more than 50, 70, or 90% of the emission comes from the line of interest) within the FWHM of the detector resolution, often referred to as line "purity." Our choice of FWHM here is deliberate, since this is a study of how well nearby lines can be separated. As noted in the

XMM/Newton User Handbook (Chapter 2, §1), "HEW indicates the detectability of a weak feature against a strong continuum and FWHM whether two closely spaced spectral lines can be resolved."

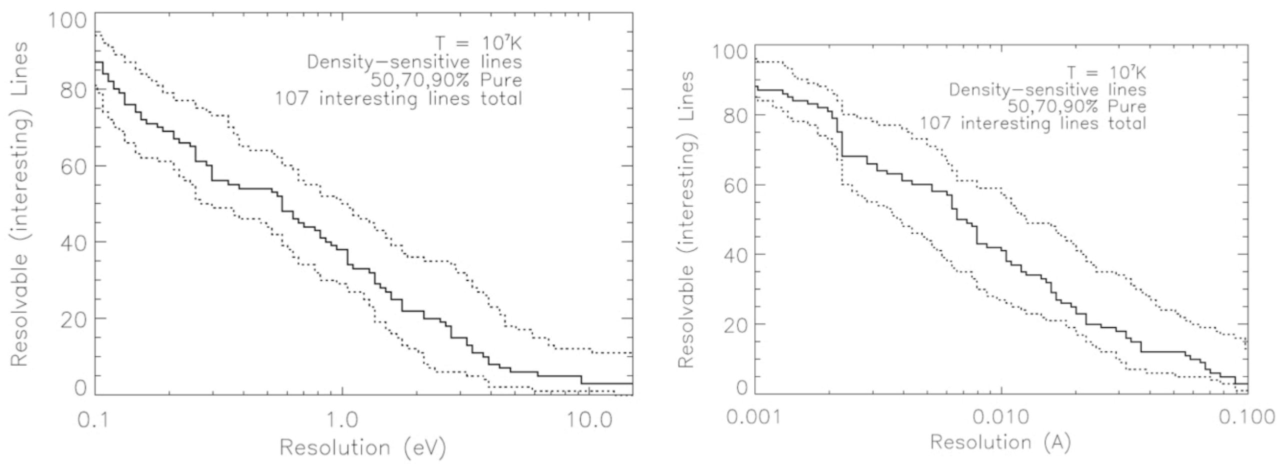

Figure 1(Left) Number of "interesting" density-sensitive lines that can be resolved, as a function of FWHM in eV. The solid line shows the number of lines if a purity of 70% is required; the dotted lines bracket this with 50% at the top and 90% at the bottom. (Right) Same, for constant-wavelength resolution in Å.

Our results are shown in Figure 1. The number of resolvable lines rises almost linearly (in log space) with decreasing FWHM, except for FWHM values larger than 4 eV or 0.03°A where only a few lines can be resolved.

References

Smith, R. K. et al. 2001, ApJ, 556, L91